<u>Original Research Article</u>

Health Benefit- Risk Analysis of Locally Cultivated Mango Fruits and Branded Mango Beverages in Adamawa State, Nigeria

ABSTRACT

In this study, the vitamin, nutrient, antinutrient and heavy metal concentrations in Powdered mango fruit juices (sachet brands) (PMFJ), Liquid mango fruit juices (LMFJ), and Fresh or raw mango fruits juices (FMFJ) were assessed toward establishing a tradeoff between their health benefits and potential health risk on consumption. The analysis show the concentration of vitamin C constituting 50-70% and Vitamin A 30-40% by composition relative to other vitamins. The highest concentration of vitamin A and C were observed in the PMFJ, and the LMFJ samples. Relative to the bioavailability of vitamin E, K, B1, B2, B6 and B12, FMFJ contains the highest concentrations compared to PMFJ and LMFJ. The results further show the highest concentration of 0.79 mg/100 g and 6.85 mg/100 g of oxalate and phytate in the FMFJ. The analysis of the mineral contents show Ca accounting for over 50%, with FMFJ containing the highest concentration (57%). The concentration of Mg, Mn, Fe, and Zinc all falls within the acceptable range to constitute any potential risk on consumption. Based on the EDI values, the dietary exposure to lead (Pb) was observed to be above the oral reference dose (RfD) values set for Pb in edibles. Further appraisal for non-carcinogenic and carcinogenic risk from Pb exposure gives a THQ values of less than one (<1) and a CRI $\leq 10^{-4}$. Overall, the results show children to be more at risk for Pb exposure than the adults. From the results, it could suffice to say that unhealthy agricultural practices and possible anthropogenic activities could be the probable reasons for the low level of vitamin A and C in the FMFJ samples. Furthermore, could probably be the contributing factors leading to the increasing use of additives and fortified functional foods to meets population demands and nutritional requirements as observed in the PMFJ and LMFJ samples respectively.

Key words: Mango, vitamin, health risk analysis, minerals, antinutrient.

1. INTRODUCTION

Due to the unhealthy practices in the global food enterprises, the assessment of food is considered necessary toward establishing a possible balance between its risks on consumption and the related beneficial health effects to human population [1, 2]. It is evident from the foregoing that, the choice of foods for healthy living encompasses the issue of availability and economic considerations. It has become apparent that low level of agricultural output has impacted heavily on food quality and nutritional requirement for human consumption. The non-availability of fresh foods, especially fruits leads to the inflow of processed/or synthetic fruits products and additives to meets population demands. Dietary supplements, formulated foods and fortified functional foods are increasingly taken over the market for fresh foods. Though these functional foods might have some of the nutritional requirements for human consumption, the aspect that distinguishes nutrient and other non-nutrient constituents and their relationship to each other are seldom included in the dietary chemistry, considering the fact that nutrient, antinutrients and presence of other trace metals and minerals influences each other availability and physiochemistry [3, 4].

Due to the complex nature of food, the absorption and metabolism of any single nutrients or minerals through some chemistry influences the absorption or metabolic pathways of another. A typical example is in the metabolism of iron. Study shows that vitamin C enhances the absorption of Iron and on the other hand, phytate can readily bind to iron and impaired its availability [1, 2, 5]. Mango (*Mangifera indica* L.) fruit by far has been traditionally utilized as an important source of calories [6], supplier of excellent phytochemicals [7], a good antioxidant [8], and dietary fiber [8]. With this myriad of potential, several researches were conducted to evaluate the proximate composition [9,10], and presence of toxic substances [11] in Mango species in Nigeria.

As mentioned earlier, balancing risk and benefits in food security and health remains a major hurdle to cross as the demand for healthy foods has been overtaken by economically motivated factors. Therefore, these study tried to establish a tradeoff between the nutrient profiles of raw/fresh mango and formulated/processed mango beverages in the market and relate its associated chemistry toward other mineral or elements on consumption. The effort is to mirror down the risk associated with nutrient availability, presence of antinutrient and other elements in the mango foods and quantify a balance to its health benefits on consumption by humans.

2. MATERIAL AND METHODS

The sample for the research work was obtained from Hong and Mubi metropolis, Adamawa State, Nigeria. Fruit juices bearing different brand names was purchased from various shops in Mubi. While the fresh mango fruits were obtained from farms in Hong and Mubi. They were grouped into three: Group 1: Powdered mango fruit juices (sachet brands) (PMFJ), Group 2: Liquid mango fruit juices (LMFJ) and Group 3: Fresh/raw mango fruits juices (FMFJ). The mango juice samples were extracted using acid digestion method according to American Public Health Association [12]. The digested samples were then analyzed for vitamin, antinutrient, and minerals. The vitamins were determined using UV/Visible spectrophotometer. The oxalate content of the foods were determined by colorimetric methods, while phytate and Cyanide content were determined based on the methods described in AOAC [13]. Atomic Absorption Spectrophotometer (AAS) (VGP 210, Buck Scientific) was used for the elemental analysis. The heavy (Trace) metals: Cadmium (Cd), Chromium (Cr), and Lead (Pd) were analyzed along with the following essential elements, Zinc (Zn), Sodium (Na), Potassium (K), Calcium (Ca) and Magnesium (Mg) and Manganese

(Mn). The data obtained was expressed as Mean ± S.D and the level of significance was set at $p<0.005$.

Elements with values above the permissible limits (PL) were further subjected for health risk assessment. For these reasons, the estimated daily intake were determined for Pb only in the respective samples using the USEPA recommended procedure described in equation 1 [14].

$$EDI = (C \times F_{IR})/BW \quad (1)$$

Where EDI is the Average Daily Intake (mg/kg body weight/day); C is the concentration of the elements in the mango samples; F_{IR} is the average daily consumption of mango [15]. The *BW* is the body weight (kg); set at 60 for an average adult and 15 for children [16]. The target hazard quotient (THQ) as described in equation 2 was used to determine the human health risk posed by the long-time exposure to the metal in the samples

$$THQ = (C\ x\ FIR\ x\ EF\ x\ ED)/\ (BW\ x\ AT\ x\ RfD)\ x\ 10^{-3} \quad (2)$$

Where, EF is the exposure frequency (365 days/year); ED is the exposure duration (70 years); *BW* is the body weight in kg; and AT is the average time for non-carcinogens (365 days/year × ED). The oral reference doses (RfDs) of 0.00035 mg/kg/day were adopted for Pb [17, 18]. The description hypothesis a THQ less than 1 to signify no associated risk, meaning the exposed population is unlikely to experience any adverse health hazard. However, if the THQ is equal to or greater than 1, then there is a potential health risk [17, 18]. The potential of Pb to induce carcinogenic and non-carcinogenic risk were assessed based on the procedure described by USEPA [14]. Cancer slope factors of 0.0085 for Pb in mg/kg/d were used in the expression in equation 3 [14,16].

$$CRI = EDI_m\ x\ CSF \quad (3)$$

Where CRI, EDI_m and CSF represent the carcinogenic risk index, estimated daily intake of the heavy metals and the cancer slope factor respectively. Carcinogenic risk index between 10^{-6} (1 in 1,000,000) and 10^{-4} (I in 10,000) indicates the tolerable lifetime risks for cancer causing agents [17].

3. RESULTS AND DISCUSSION

The results in Fig 1 shows the nutrient composition in the PMFJ, LMFJ and FMFJ samples respectively. From the results, vitamin C (mg/100g) was observed to constitute about 68 %, 60 % and 51 % followed by vitamin A (IU/100g) with 30 %, 39 % and 31 % in the PMFJ, LMFJ and FMFJ samples respectively. Relative to other vitamins (B1, B2, B6, E, and K), the FMFJ sample was observed to constitute up to 18 % compared to 2 % recorded for the PMFJ, and LMFJ samples respectively. The highest concentration of 0.33 mg/100g, 0.49 mg/100g, 0.13 mg/100g, 0.50 mg/100g, 6.49 mg/100g and 0.12 mg/100g were observed for B1, B2, B6, B12, E, and K respectively in the FMFJ. The high level of vitamin A and B in the PMFJ, and LMFJ could be due to either fortification [19] or from the combination of mango varieties in the processing. Though, several research work reported high content of vitamin A and C in the raw/fresh mango juice [9, 20], this study however gives a contrary results, showing low amount of the vitamin A and C in the FMFJ compared to the PMFJ and LMFJ. It is therefore evident from the foregoing that anthropogenic activity and other agricultural practices may have influences the mineral/nutrient chemistry in the soil and it translocation or bioavailability in the fruits [21]. This changes in nutrient chemistry may have influence the fortification of the PMFJ and LMFJ with vitamin A and C in other to meets population demands and nutritional requirements.

Even though PMFJ and LMFJ contained higher level of vitamin A and C, it will suffice to say that the complementary efficacy of the vitamin A and C will be more effective in the FMFJ compared to the others, considering it containing reasonable proportion of vitamin B1, B2, B6, E, K and high proposition of fiber. Vitamin A enhances eye vision, dermal health while vitamin K support protein hemostasis in the blood, bones, kidneys, and facilitate clotting of wounds. Vitamin B1 and B2 support energy production and enhances the body's ability to utilize other B vitamins. In addition to the synthesis of hemoglobin, vitamin B6 also facilitate energy storage by utilizing available protein and glycogen in the body while the B12 vitamin support folate in DNA synthesis [22-24]. Intestinal absorption of vitamin A is enhanced in the presence of Vitamin E, increasing their antioxidants and immune response potential toward xenobiotics and other proinflammatory agents. Vitamins C and E work synergistically to boost their antioxidant defense potential, with vitamin C regenerates vitamin E [22, 23]. These synergy based on the composition of the vitamins in the samples could be best promoted and made available on the consumption of the FMFJ compared to PMFJ and LMFJ thereby maintaining prooxidant-antioxidant balance [22, 25]. Vitamin E in particular shield lipids against peroxidation by reacting with lipid peroxyl radicals to form a relatively stable lipid hydroperoxide thereby interrupting the radical chain reaction [25, 27]. In similar fashion, vitamin C scavenge peroxyl radicals, inhibiting the onset of lipid peroxidation and was further observe to support the vitamin E in regenerating the radical scavenging potential of tocopherol by reducing the activity of tocopheroxyl radical [25, 28-29].

The results further show the presence of oxalates and phytates in all the samples. Cyanides was not detected in the samples. The highest concentrations of oxalates (4.79 mg/100g) and phytates (6.85 mg/100g) were observed in the FMFJ samples. The low level of these antinutrient in the PMFJ, and the LMFJ could be connected to processing. Studies shows that preparation and processing can affect the nutritional value by destroying labile nutrients and antinutrient [30, 31]. Even though the concentration in this study was observed to be higher than the 1.49 ±0.01 mg/100g (oxalates) and 1.44 ±0.01 mg/100g (phytates) reported by Fowomola, [9] in some Nigeria mango fruits, the values were significantly lower compared to other plant Food of South Eastern Nigeria [32]. In the study as reported by Ndie and Okaka [32] the levels of phytate ranges from 23.5-130.65 mg/kg, while oxalate falls between 4.7-95.6 mg/kg. Exposure to dietary soluble oxalates reduces the bioavailability of calcium, and predispose individual to kidney stones [33]. Oxalic acid binds readily with nutrients, Ca^{2+}, Fe^{2+}, and Mg^{2+} and forms water soluble salts with Na^{+}, K^{+}, and $NH4^{+}$ ions in the body, thus reducing their bioavailability. Dietary intake of oxalates ordinary falls from 44-351 mg/day and a mean intake of 152 mg/day [34]. From this values, only about 1 to 22% of the ingested oxalate is absorbed in humans [35], with most of oxalate-chelating minerals excreted in urine and feces [36]. Similar to oxalate, the negatively charged ion on Phytate conferred on it's the ability to impaired the bioavailability of divalent, and trivalent mineral ions such as Zn^{2+}, $Fe^{2+/3+}$, Ca^{2+}, Mg^{2+},Mn^{2+}, and Cu^{2+} [35; 37-38]. Though phytate and oxalate were detected in all the samples in this study, the concentration are observed to be relatively below the level of concerns [34, 39]. More so the risk from antinutrient as discussed above depends largely on their level of excretion and the frequency of consumption [32, 35].

Despite the fact that oxalate and phytate are considered antinutritional, there were however reported to support other important and essential chemistry [40]. Their metal chelating potential helps reduces the induction of oxidative stress from reactive species on the epithelial cells thereby impairing the onset of mutagenesis [41, 42]. Dietary phytate was observed to significantly reduce the serum concentration of lead [43], and reported to inhibit its absorption, reduces its accumulation in the bones, blood and the liver [44, 45]. Similarly, formation of Cd–phytate complexes were reported to explicably reduces the absorption of Cd [46]. Studies shows that phytates participated in reducing the level of serum cholesterol, triglycerides and carbohydrate overload [47, 48]. While oxalates promote the onset of kidney stones, phytates on the other were reported to halts its formation by inhibiting calcium salt crystallisation [49.50]. In another study, phytate was observed to exert a neuro-protective effect in a cultured cell model of Parkinson's disease [51]. Similarly, increased level of vitamin C has been shown to counteract the phytate inhibitory potential [52]. The preference of PMFJ, and LMFJ over FMFJ due to the presence of the antinutrient will invariable deny the consumer from other important benefits of the antinutrients discussed above, considering the amount detected to be of no significance.

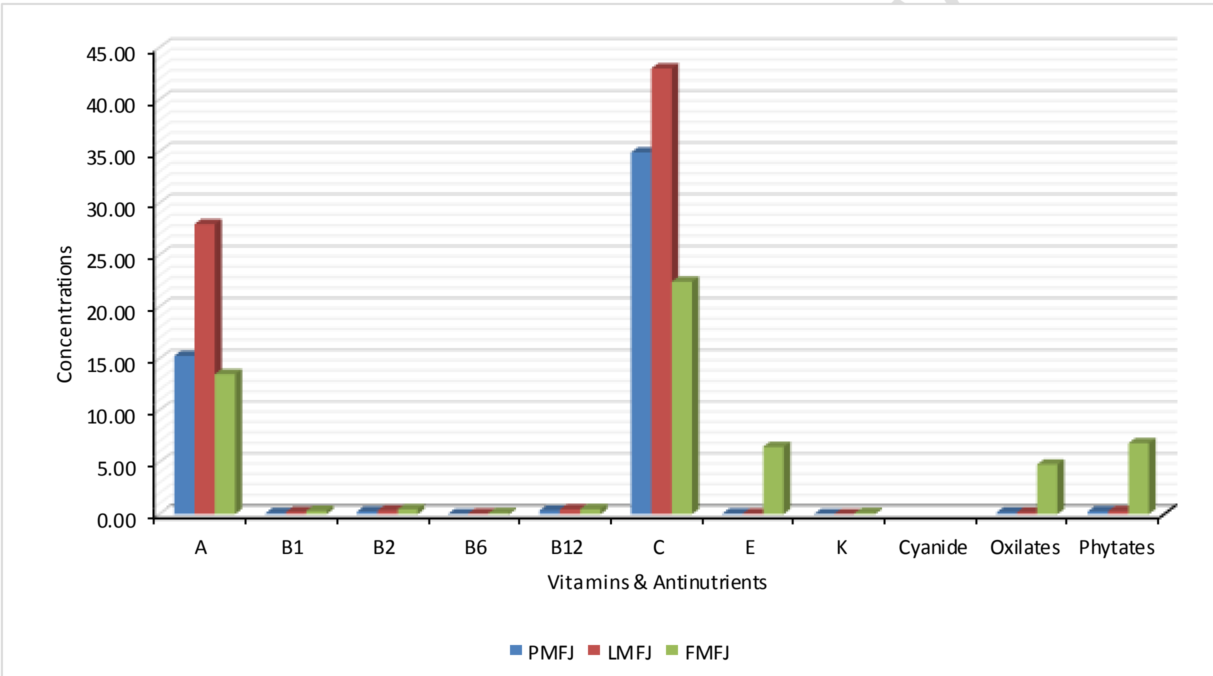

Figure 1. Concentration of vitamins (A (IU/100g), B1, B2, B6, B12, E, and K (mg/100g)) and antinutrients (mg/100g) in the PMFJ, LMFJ, and FMFJ. Results are presented as Mean ± SD of triplicate analysis

With the exception of Cd and Pb, the rest of the elements (Na, Mg, K, Ca, Mn, Fe, and Zn) are considered physiologically essential in maintaining healthy body systems. Their concentrations in the samples especially Mn, Fe Mg and Zn were observed to all fall below the permissible limits (PL) allowed in edibles [53]. The analysis of the mineral contents shows Ca accounting for over 50% in all the samples with the LMFJ containing the highest amount (57%). The next mineral with the highest concentration is Mg followed by K. the percentage concentration follow the decreasing other 16% (LMFJ) < 20% (PMFJ) < 24% (FMFJ), while 14%, 16% and 8% were recorded for K in PMFJ, LMFJ and FMFJ respectively. The concentration of Fe, Mn and Zn all falls ≤1%. Chromium was not detected in all the samples and Cd was found only in the PMFJ and LMFJ Samples. High concentrations of these essential minerals were also reported by Saeed *et al* [54] in Pakistani mangoes. The results presented by Dangana *et al* [11] for different mango varieties collected in Niger state, Nigeria show concentration in the rage of 0.10 - 1.30, 0.59 -

1.84, 0.03 - 0.16 and 0.50 - 0.80 mg/L for Mn, Fe, Cu, and Pb. The highest mean values for the respective metals were detected in *Binta* Sugar mango, Kerosene mango, Kerosene mango and Kerosene mango fruits respectively. With the exception of Pb which was detected to be above the PL, the level of Mn, Fe, and Cu in the respective samples were found to be below the PL. [11]. It was also found that Ca (~14.79 mg/kg), Mg (~10.46 mg/kg), Na (~6.327 mg/kg), K (~166.33 mg/kg) and Zn (2.85 mg/kg) were predominant among the major elements in some fruits from Turaba District (Saudi Arabia) [55].

Calcium support the normal transmission of nerve impulses and neuromuscular activities. Activates the activity of adenosine triphosphatase (ATPase), succinic dehydrogenase, lipase and the conversion of prothrombin to thrombin [23]. Sodium and Potassium helps in maintaining the osmotic pressure of the body fluids by regulating membrane potentials and establishing acid-base balance. And similar to Ca^{2+} support the transmission of nerve impulses and other neuromuscular functions [61]. Magnesium physiological participate in activating phosphate-transferring enzymes, pyruvic acid carboxylase, and pyruvic acid oxidase reactions [61]. Iron is a constituent of haemoglobin, participated in the biological oxidation of cytochromes and an essential cofactor in the synthesis of neurotransmitters [62]. Manganese supports the biosynthesis of proteoglycans [61] and support pyruvate metabolism [23]. Zinc influences the metabolism and bioavailability of Vitamins A and E [63]. As an integral constituent of insulin also serves as a cofactor in many enzymatic reactions that support cell replication, gene expression, DNA and RNA polymerase [23, 61, 64]

All these minerals were observed to synergistically interact and complement each other. And further observed to support the metabolic action of some vitamins [23]. Vitamins and minerals work synergistically, and romantically in a way were a deficiency in one might influence the optimal operational capability in another and vice versa. Non-heme iron absorption increases in the presence of Vitamin A, increasing the bioavailability of pro-vitamin A. Vitamin C also regulates the uptake and metabolism of iron. Zinc support the physiological transport of Vitamin A and further boost the antioxidant potential of Vitamin B3. Magnesium on the other hand support thiamin-dependent enzymatic reaction, facilitate the conversion of thiamin (vitamin B1) to its biologically active forms and enhances the uptake of vitamin B6. Potassium and Sodium enhances calcium reabsorption [24]

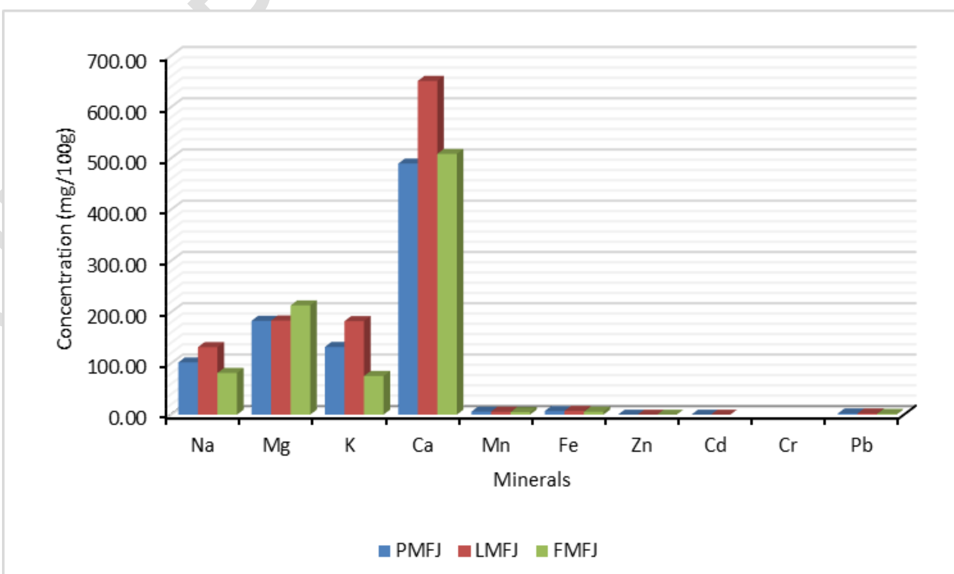

Figure 2. Concentration of mineral elements and heavy metals in the PMFJ, LMFJ, and FMFJ. Results are presented as Mean ± SD of triplicate analysis

Unlike Cd, the concentration of Pb ions in the samples were observed to be higher than the PL of 0.35 mg/kg set by the FAO/WHO [53]. Similar results were also reported in Mango varieties collected in other part of Nigeria [11]. Substantial amount of Cd, and Pb were also reported in Mango species from Pakistan [54], Libya [56]**,** **T**anzania **[57]**, Kenya [58], Poland [59], and Iran [60]. Lead is a classic example of carcinogens, even at minute concentrations could be highly toxic [65], known to impaired cognitive development in children, facilitate the development of high blood pressure and cardiovascular diseases [65]. For these reasons, carcinogenic and non-carcinogenic risk assessment was conducted for Pb ion only and the results presented in Table 1. From the results the exposure to Pb were observed to be higher in the PMFJ and LMFJ showing an EDI of 1.3E-02 mg/kg/day and 1.4E-02 mg/kg/day for the adults and 5.4E-02 mg/kg/day and 5.5E-02 mg/kg/day in children respectively. Less probability of exposure were observed following the consumption of the FMFJ showing an EDI values of 8.5E-03 mg/kg/day and 3.4E-02 mg/kg/day for the adults and children respectively. From all the results, the EDI values were observed to be above the RfD of 3.5E-04 mg/kg/day set for Pb; indicating potential risk from Pb exposure following the consumption of the samples. Risk Assessment conducted by Mausi *et al* [58] in mango fruits from Keya, similarly shows the Daily Intake of Pb to be significant. However, further appraisal for non-carcinogenic risk based on the THQ analysis for Pb was observed to be <1 for all the samples. Similarly, the assessment of carcinogenic risk from Pb exposure also shows a CRI values $\leq 10^{-4}$. These results draws the obvious conclusion that the respective samples are safe for human consumption. Overall, the results show children could be more susceptible to a higher level of exposure dose compared to the adults. The vulnerability of children to non-carcinogenic and carcinogenic risks compared to the adults as shown in the results in a more practical sense could be linked to their higher intake rates per unit body weight [16, 66-67]. Furthermore, it will suffice to say that the replacement of fresh fruits for processed brands will expose consumers to a higher level of health risk from heavy metals and deficiency of some vitamins may suffice. Therefore, the consumption of fresh fruits, especially fresh mango in addition to its high fiber contents will provide the much desired nutrient-mineral balance against the potential risk from antinutrient and other trace heavy metals.

Table 1. Estimated daily intake (EDI) rate, Target hazard quotient (THQ) and Cancer risk index (CRI) for Pb in the Samples

	EDI (mg/kg/day)		THQ		CRI	
	Adult	Children	Adult	Children	Adult	Children
PMFJ	1.3E-02	5.4E-02	3.8E-02	1.5E-01	1.1E-04	4.6E-04
LMFJ	1.4E-02	5.5E-02	3.9E-02	1.6E-01	1.2E-04	4.7E-04
FMFJ	8.5E-03	3.4E-02	2.4E-02	9.7E-02	7.2E-05	2.9E-04

5. CONCLUSION

It is widely assumed that natural fruits are richer in vitamins and minerals than processed functional fruits product. The result from this study show a change in the trend showing low content of the vitamins in the FMJF compared to the PMFJ and LMFJ, pointing out a destress call to regulate some unhealthy agricultural practices. However, the analysis further revealed that the full potential of the A and C vitamin will be fully realized in the presence of other vitamins such as B1, B2, B6, E, and K which was observed to be more in the FMJF. Similarly, higher concentration of the essential elements Na, Mg, K, Ca, Mn, Fe, and Zn further reiterate the importance of consuming FMJF compared to the PMFJ and LMFJ considering the complementary role played by such elements in boosting vitamin antioxidant potential. Even though oxalate and phytate were observed to be high in the FMFJ, at this low concentration and owing to their high metal-chelating potential, could participate in reducing the absorption potential of heavy metals. High EDI values above the RfD set for Pb were observed for PMFJ and LMFJ, however, the health risk assessment conducted for the same samples gave a THQ of <1 and a CRI of 10^{-4} suggesting that the population are unlikely to experience any adverse health hazard from Pb exposure. Though the overall results show low level for both carcinogenic and non-carcinogenic risk, the results further draws the obvious conclusion that the consumption of branded mango products could expose consumers to potential risks from heavy metals. Further points that the consumption of fresh/raw mango fruits could boost the vitality and health of the body and therefore should be encouraged.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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